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Stickle

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(54) **INFERRING APPLICATION INVENTORY**

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(51) **Int. Cl.**

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H04L 29/08	(2006.01)
H04L 29/06	(2006.01)
G06F 11/30	(2006.01)
G06F 11/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 41/085*** (2013.01); ***G06F 11/006*** (2013.01); ***G06F 11/3003*** (2013.01); ***G06F 11/3409*** (2013.01); ***H04L 43/028*** (2013.01); ***H04L 43/04*** (2013.01); ***H04L 63/1433*** (2013.01); ***H04L 63/20*** (2013.01); ***H04L 67/10*** (2013.01); *G06F 11/3452* (2013.01); *G06F 2201/865* (2013.01); *H04L 43/0817* (2013.01); *H04L 43/16* (2013.01)

(58) **Field of Classification Search**

CPC H04L 43/06
USPC 709/224
See application file for complete search history.

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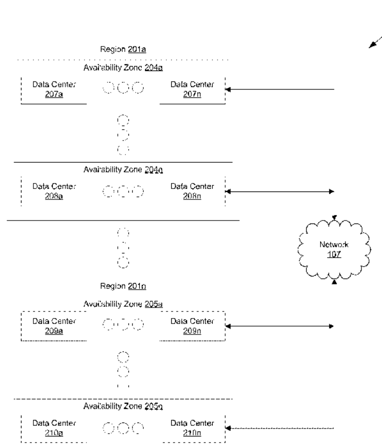
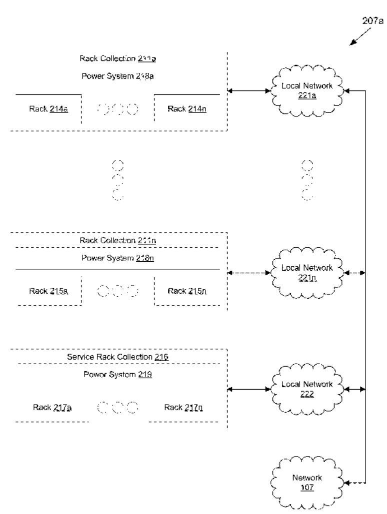
(74) *Attorney, Agent, or Firm* — Thomas | Horstemeyer, LLP

(57) **ABSTRACT**

Disclosed are various embodiments for an application inventory application. Computing resource usage data and configuration data is obtained for machine instances executed in a cloud computing architecture. The usage data and configuration data are used as factors to identify applications executed in the machine instance. Reports embodying the application identifications are generated.

24 Claims, 9 Drawing Sheets





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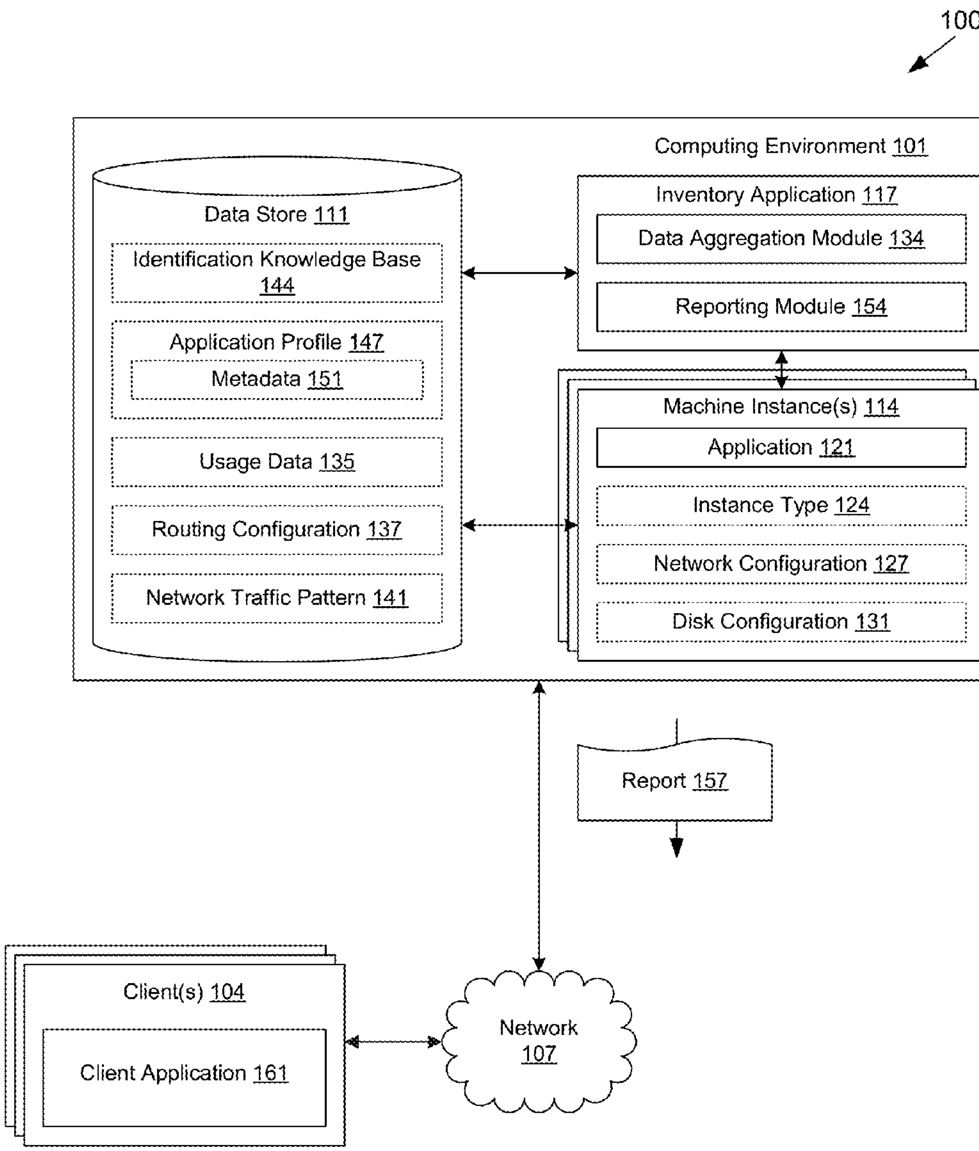

100
Computing Environment 101
Data Store 111
Identification Knowledge Base 144
Application Profile 147
Metadata 151
Usage Data 135
Routing Configuration 137
Network Traffic Pattern 141
Inventory Application 117
Data Aggregation Module 134
Reporting Module 154
Machine Instance(s) 114
Application 121
Instance Type 124
Network Configuration 127
Disk Configuration 131
Report 157
Client(s) 104
Client Application 161
Network 107

FIG. 1

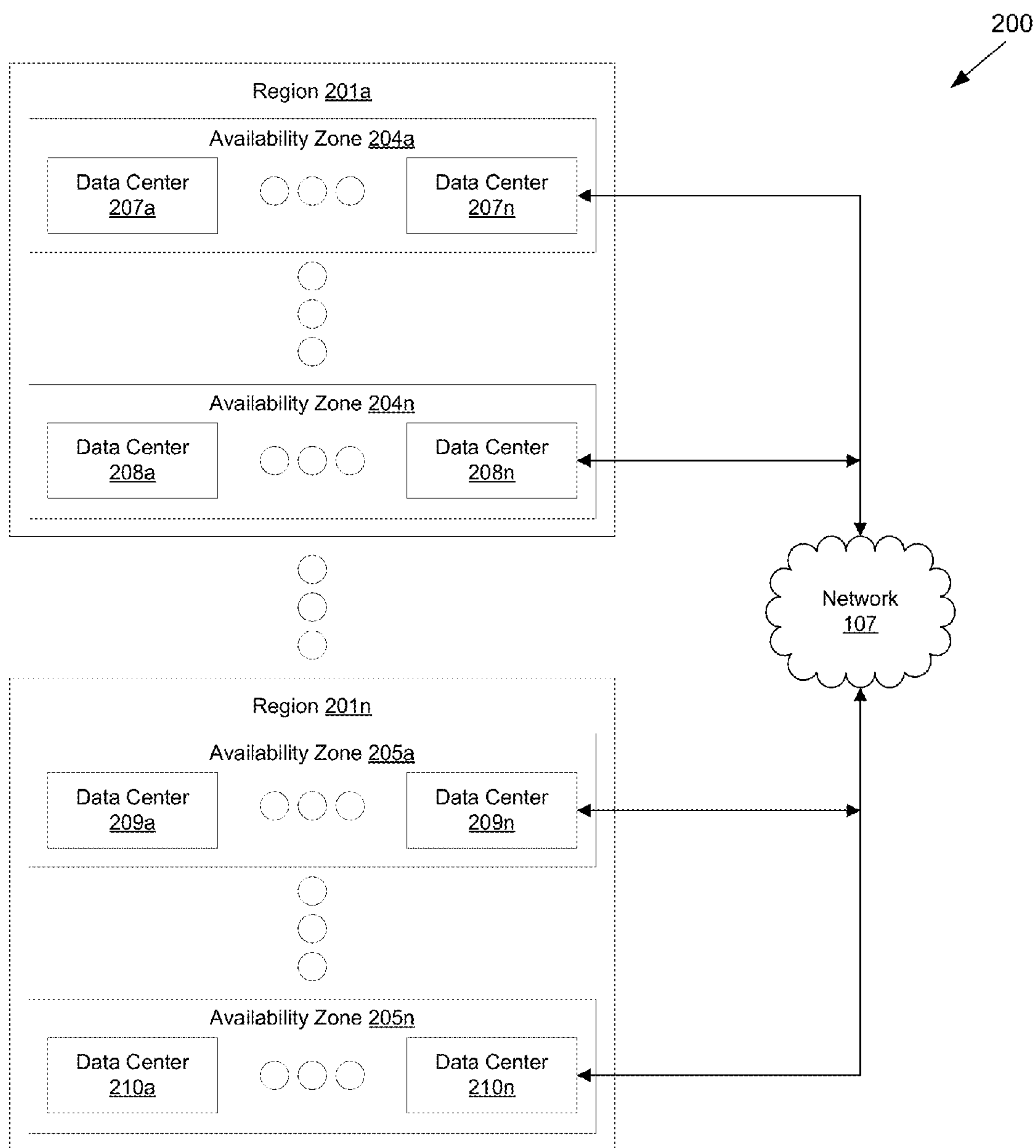

200
Region 201a
Availability Zone 204a
Data Center
207a
Data Center
207n
Availability Zone 204n
Data Center
208a
Data Center
208n
Network
107
Region 201n
Availability Zone 205a
Data Center
209a
Data Center
209n
Availability Zone 205n
Data Center
210a
Data Center
210n

FIG. 2A

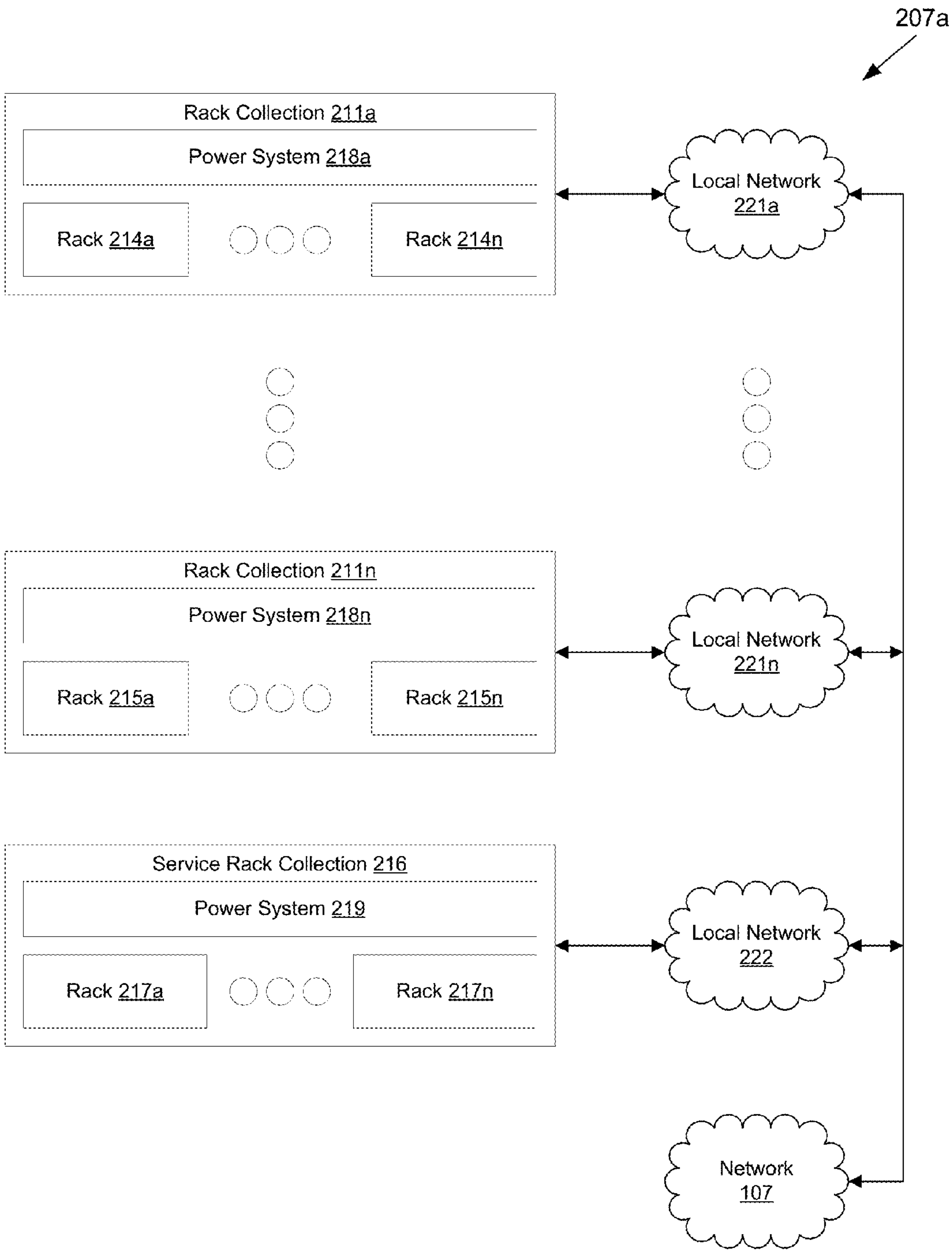

207a
Rack Collection 211a
Power System 218a
Rack 214a
Rack 214n
Local Network 221a
Rack Collection 211n
Power System 218n
Rack 215a
Rack 215n
Local Network 221n
Service Rack Collection 216
Power System 219
Rack 217a
Rack 217n
Local Network 222
Network 107

FIG. 2B

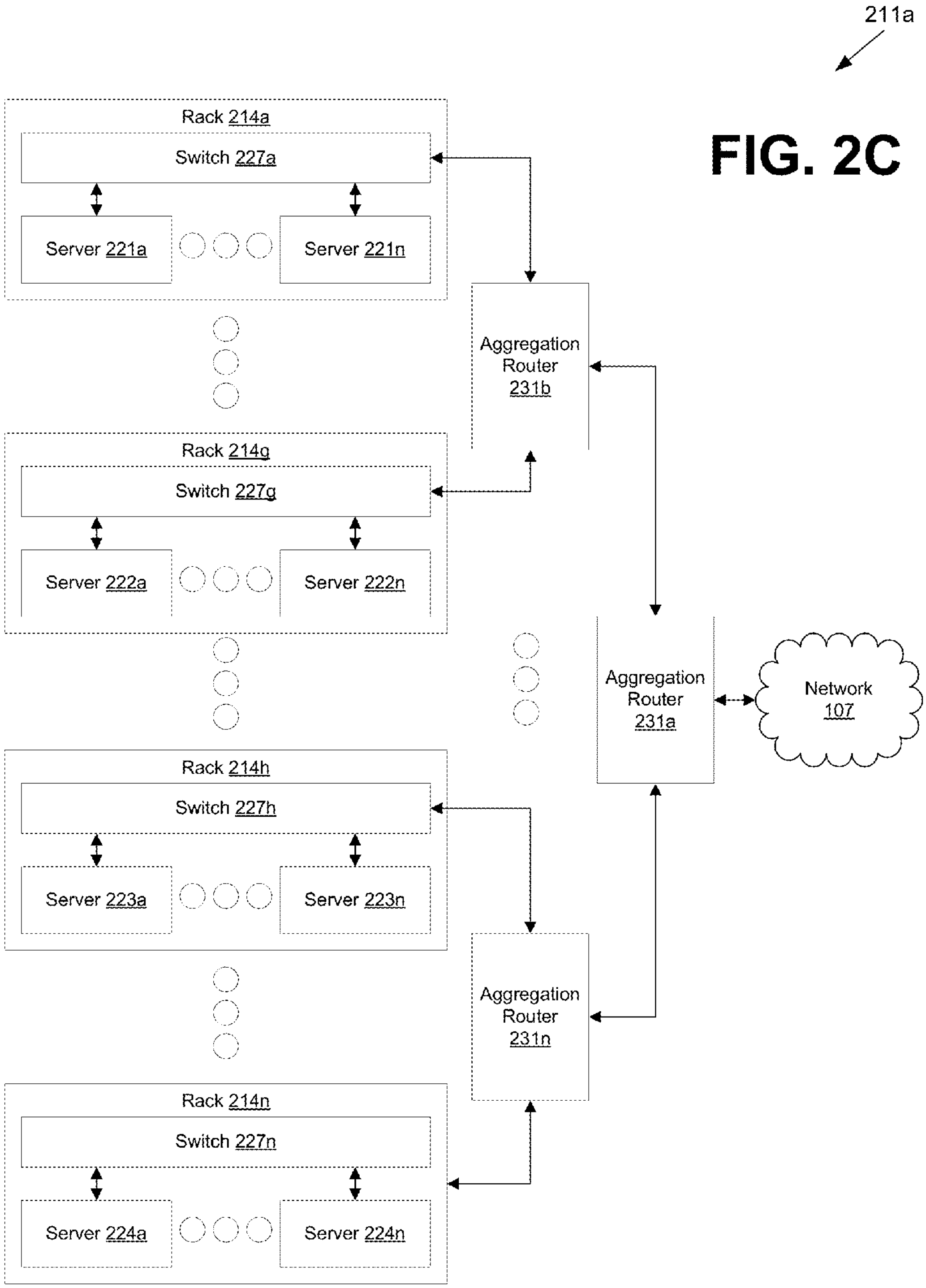

211a
Rack 214a
Switch 227a
Server 221a
Server 221n
Aggregation Router 231b
Rack 214g
Switch 227g
Server 222a
Server 222n
Aggregation Router 231a
Network 107
Rack 214h
Switch 227h
Server 223a
Server 223n
Aggregation Router 231n
Rack 214n
Switch 227n
Server 224a
Server 224n

FIG. 2C

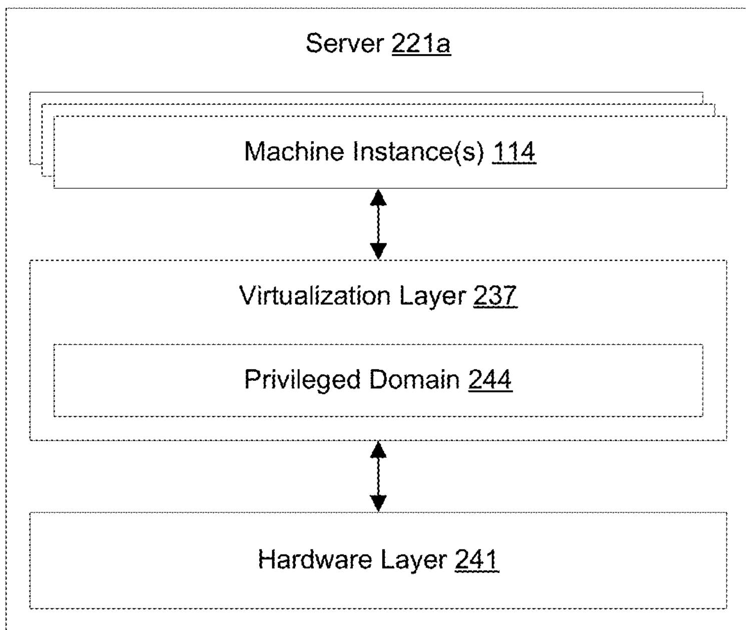
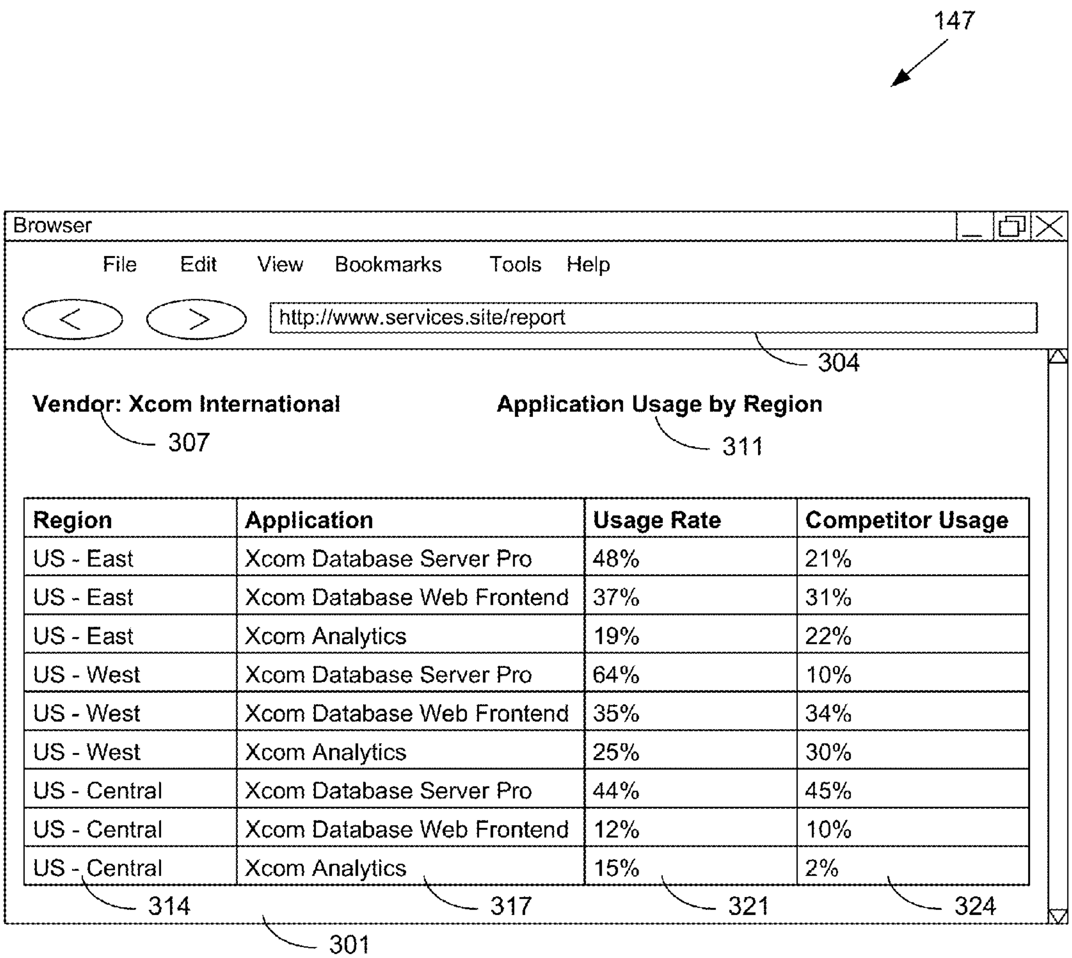

Server 221a
Machine Instance(s) 114
Virtualization Layer 237
Privileged Domain 244
Hardware Layer 241

FIG. 2D


147
Browser
File Edit View Bookmarks Tools Help
http://www.services.site/report
304
Vendor: Xcom International
307
Application Usage by Region
311

Region	Application	Usage Rate	Competitor Usage
US - East	Xcom Database Server Pro	48%	21%
US - East	Xcom Database Web Frontend	37%	31%
US - East	Xcom Analytics	19%	22%
US - West	Xcom Database Server Pro	64%	10%
US - West	Xcom Database Web Frontend	35%	34%
US - West	Xcom Analytics	25%	30%
US - Central	Xcom Database Server Pro	44%	45%
US - Central	Xcom Database Web Frontend	12%	10%
US - Central	Xcom Analytics	15%	2%

314
317
321
324
301

FIG. 3A

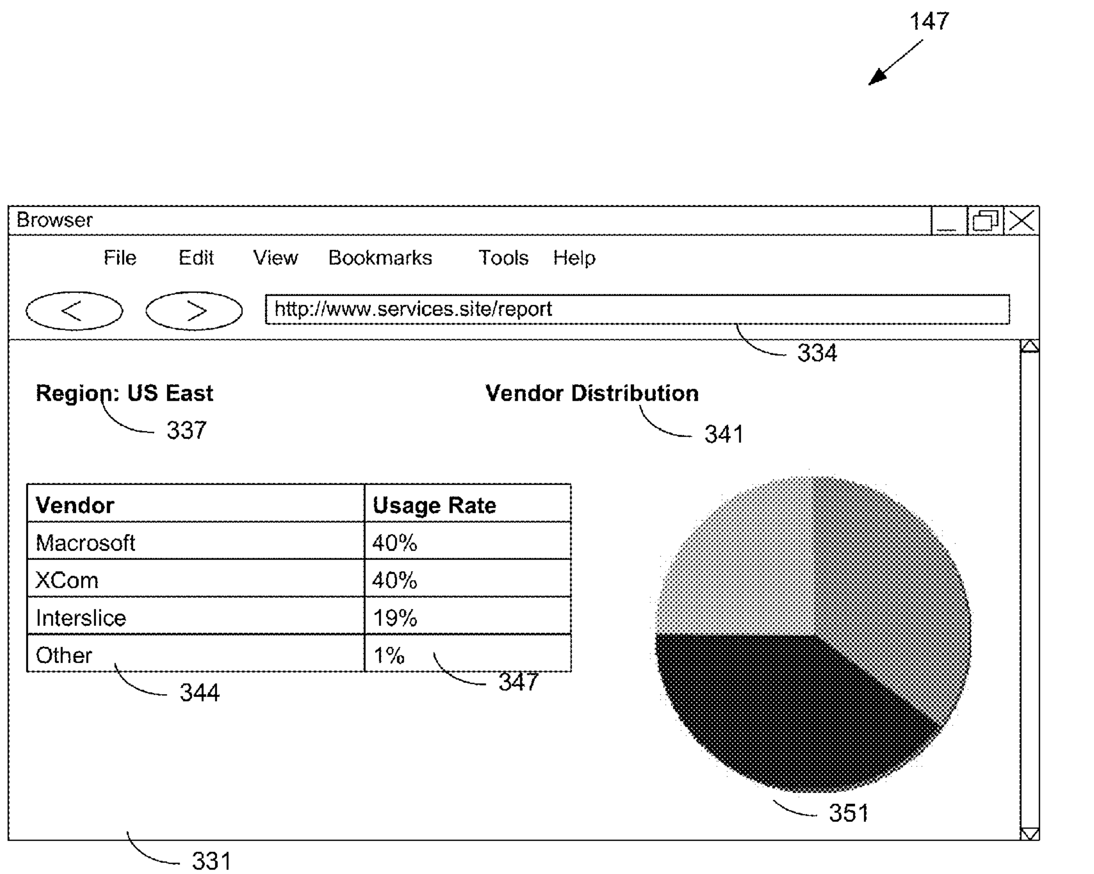

147
Browser
File
Edit
View
Bookmarks
Tools
Help
http://www.services.site/report
334
Region: US East
337
Vendor Distribution
341
Vendor
Usage Rate
Macrosoft
40%
XCom
40%
Interslice
19%
Other
1%
344
347
351
331

FIG. 3B

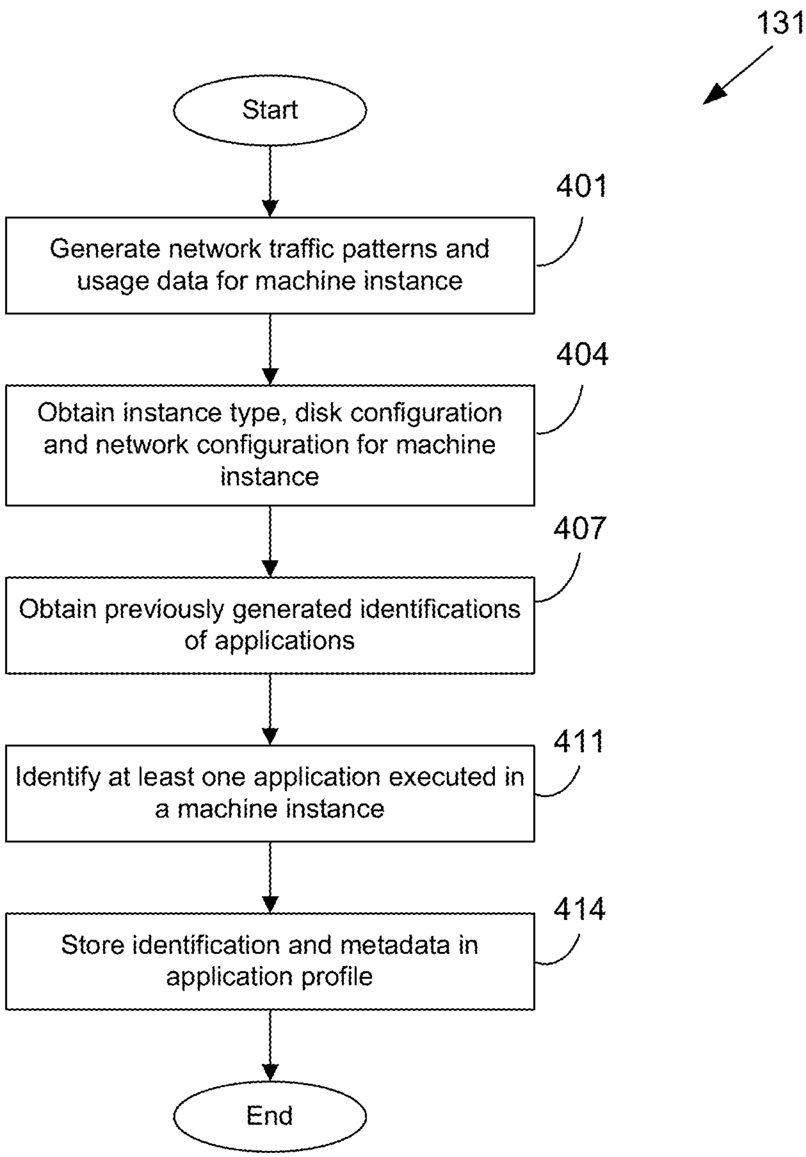

131
Start
Generate network traffic patterns and usage data for machine instance
401
Obtain instance type, disk configuration and network configuration for machine instance
404
Obtain previously generated identifications of applications
407
Identify at least one application executed in a machine instance
411
Store identification and metadata in application profile
414
End

FIG. 4

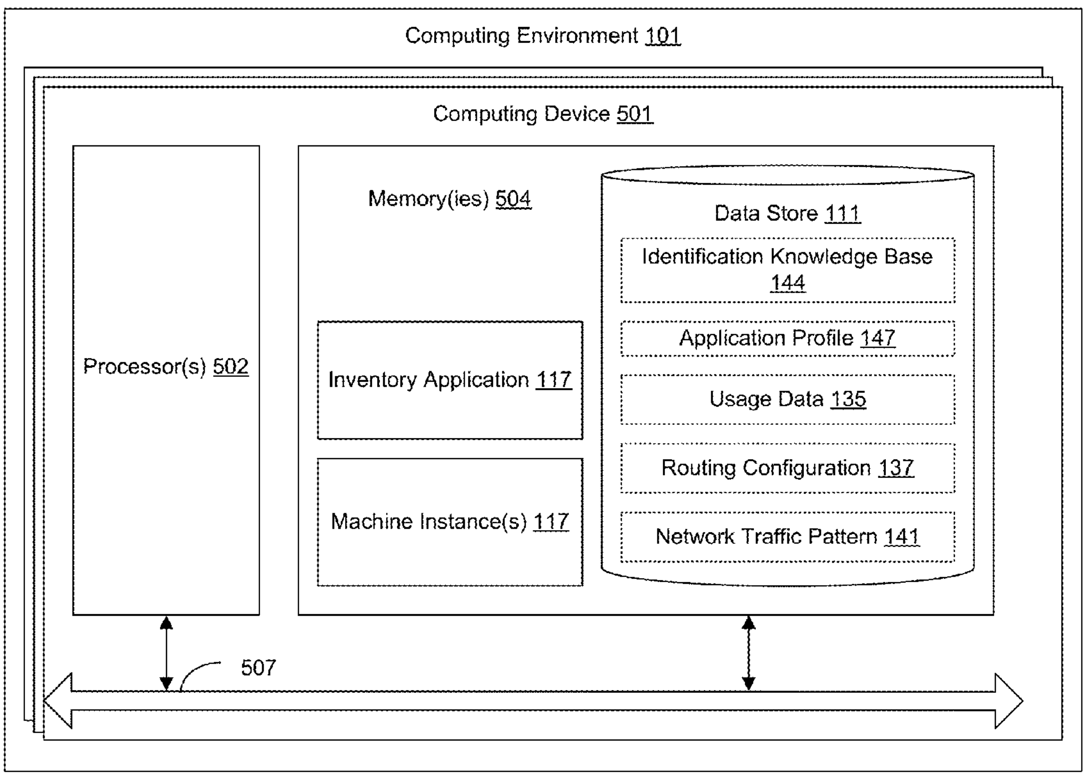

Computing Environment 101
Computing Device 501
Processor(s) 502
Memory(ies) 504
Data Store 111
Identification Knowledge Base 144
Application Profile 147
Usage Data 135
Routing Configuration 137
Network Traffic Pattern 141
Inventory Application 117
Machine Instance(s) 117
507

FIG. 5

INFERRING APPLICATION INVENTORY

BACKGROUND

A cloud computing infrastructure service allows for a variety of services and applications to be executed within its infrastructure. Determining what services and applications are implemented within the various components of the infrastructure can be beneficial.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a drawing of a networked environment according to various embodiments of the present disclosure.

FIG. **2**A is a drawing of an example region-level data center architecture according to various embodiments of the present disclosure.

FIG. **2**B is a drawing of an example data center-level data center architecture according to various embodiments of the present disclosure.

FIG. **2**C is a drawing of an example rack-level data center architecture according to various embodiments of the present disclosure.

FIG. **2**D is a drawing of an example server-level data center architecture according to various embodiments of the present disclosure.

FIGS. **3**A and **3**B are drawings of an example of a user interface rendered by a client in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

FIG. **4** is a flowchart illustrating one example of functionality implemented as portions of an inventory application executed in a computing environment in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

FIG. **5** is a schematic block diagram that provides one example illustration of a computing environment employed in the networked environment of FIG. **1** according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

Cloud computing infrastructures allow for customers to implement virtual machine instances that execute on a computing device. The customers can, for example, implement an operating system and application suite of their choice in the machine instance. Often, the cloud infrastructure is modeled using a split security model, where the customer has exclusive access to the root functionality of the machine instance, while the cloud service provider has exclusive access to the underlying cloud computing functionality. This prevents the cloud service provider and customer from interfering with the operation of their respective services, and rests the responsibility for maintenance and configuration of the services in their respective administrators.

As the cloud service provider does not generally have root access to the customer machine instances and thus cannot inspect a running machine instance, the cloud service provider does not know what applications are being executed in

the machine instances. Such information would be useful to independent software vendors who provide software to the cloud service provider's customer's to facilitate better marketing of their products. Such information would also be useful to the customers implementing the machine instances in order to inform them of software updates, best practice compliance, security vulnerabilities, or other information. In many cases this information can be aggregated, or only used if opted-in to by the customer, such as not to inadvertently divulge confidential or personally identifiable information.

While this information is not generally available directly, data gathered from the environment outside the machine instance may provide an indication as to the applications running inside the machine instance. For example, a particular open network port may be the default port for a particular application, indicating that this application may be executed in the machine instance. As another example, a network routing configuration may route network traffic to the machine instance, but not from the machine instance, which may be indicative of a database server application. Disk space allocated for the machine instance or disk redundancy configurations may also indicate a type of application being executed in the machine instance. Other factors may also be considered in attempting to identify the type of applications being executed in a machine instance.

Additionally, the factors may be taken in aggregate to identify multiple applications, which may comprise a suite of software applications that work together across many servers and/or machine instances to provide a particular service. Example services could be business intelligence services, customer relationship management (CRM) services, human resource management systems (HRMS), enterprise performance management systems (EPM), supply chain management systems (SCM), among many others. Example factors could be that a machine instance may have a first open network port known to be the default port for a database server used by a particular service. The machine instance, or another associated machine instance, may also have a second open network port known to be the default port for an analysis service known to be used in conjunction with the database server. Individually, these open ports as defaults may indicate their respective applications, but in aggregate there is a greater likelihood that both the database server and analysis server are being executed as a composite software suite provided by a vendors. For example, Vendor A may provide business intelligence software components that comprise an SQL database, a data warehouse, and analysis modules that run on a plurality of servers and/or virtual machine instances. Another vendor, Vendor B, may provide similar business intelligence software, but the software components, architecture, and flow of data between the components may vary (as well as firewall information, port information, network topology, data transmission characteristics (bandwidth, flow, burstiness, etc.), virtual machine instance sizes, etc.). By analyzing these characteristics in aggregate across multiple instances and/or computer systems an inference can be made as to which Vendor's software service is being executed by the customer.

An inventory application aggregates data related to the operation and configuration of a machine instance, including hardware usage, network configurations, network routing configurations, disk configurations, applications known to be executed in the machine instance, or other data. The aggregated data is then compared to known profiles of applications to identify the applications executed in the machine instance. The identifications may be stored along with metadata in a data store for later use in generating analytics reports embodying application usage.

In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same.

With reference to FIG. **1**, shown is a networked environment **100** according to various embodiments. The networked environment **100** includes a computing environment **101**, and a client **104**, which are in data communication with each other via a network **107**. The network **107** includes, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, or other suitable networks, etc., or any combination of two or more such networks.

The computing environment **101** may comprise, for example, a server computer or any other system providing computing capability. Alternatively, the computing environment **101** may employ a plurality of computing devices that may be employed that are arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices may be located in a single installation or may be distributed among many different geographical locations. For example, the computing environment **101** may include a plurality of computing devices that together may comprise a cloud computing resource, a grid computing resource, and/or any other distributed computing arrangement. In some cases, the computing environment **101** may correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources to a customer may vary over time.

Various applications and/or other functionality may be executed in the computing environment **101** according to various embodiments. Also, various data is stored in a data store **111** that is accessible to the computing environment **101**. The data store **111** may be representative of a plurality of data stores **111** as can be appreciated. The data stored in the data store **111**, for example, is associated with the operation of the various applications and/or functional entities described below.

The components executed on the computing environment **101**, for example, include machine instances **114**, an inventory application **117**, and other applications, services, processes, systems, engines, or functionality not discussed in detail herein. The machine instances **114** comprise a virtualized instance of an operating system to facilitate the execution of one or more applications **121**. Execution of such applications may open network ports, communicate network traffic, initiate system processes, perform disk accesses, or other functionality within the machine instance **114**. The configuration and other parameters of the machine instance **114** may be defined by a customer, a system administrator of the computing environment **101**, based at least in part on default parameters, or by another approach.

The configuration of the machine instances **114** may be associated with instance type **124** defining an amount of access to computing resources of the computing environment **101** in executing the machine instance **114** and associated applications **121**. The instance type **114** may define parameters such as an amount of disk space allocated to the machine instance, a maximum or average estimated central processing unit (CPU) usage rate, a maximum or average estimated graphics processing unit (GPU) usage rate, a maximum or average estimated disk access rate, or other parameters. Such parameters may also be defined independent of an instance type **114** in some embodiments.

A machine instance **114** may also have a network configuration **127** defining network traffic permissions, network traffic routing permissions, or other data. For example, a network configuration **127** may define a subset of network ports of the machine instance **114** through which the machine instance **114** will accept traffic. The network configuration **127** may also restrict for which networking protocols the machine instance **114** will accept traffic. The networking configuration **127** may also restrict from which network addresses the machine instance **114** will accept, such as an Internet Protocol (IP) address range, a subset of defined IP addresses, a subset of defined Media Access Control (MAC) addresses, or other network addresses.

The inventory application **117** is executed to identify applications **121** being executed in the machine instances **114** implemented in the computing environment **101**. To this end, the inventory application **117** implements a data aggregation module **134** to aggregate data relating to the interoperability between machine instances **114** which may include the configuration of machine instances **114**, as well as usage data **135** associated with a machine instance **114** indicative of a usage of computing resources of the computing environment **101** by the machine instance. For example, aggregating usage data **135** by the data aggregation module **134** may comprise sampling a CPU usage rate, a GPU usage rate, bandwidth usage, disk access rate, memory usage, or other data.

Configuration data aggregated by the data aggregation module **134** may comprise obtain a routing configuration **137** defining how network traffic is routed amongst machine instances **114**. For example, the routing configuration **137** may define a connection to a load balancer for allocation of network traffic. The routing configuration **137** may also define machine instances **114** or network addresses to or from which a current machine instance **114** routes traffic. The routing configuration **137** may also comprise other data. Obtaining the routing configuration **137** may comprise loading the routing configuration **137** from a data store, querying an application program interface (API) or other functionality of a networking component such as a load balancer, switch, or router, or by another approach.

The data aggregation module **134** may also sample network traffic patterns **141** associated with communications between machine instances **114** or communications between machine instances **114** and an external network **107**. Network traffic patterns **141** may comprise networking protocol usage, port usage, packet size, packet contents, network traffic sources or destinations, or other data. The data aggregation module **134** may, for example, employ a packet inspection functionality to extract network packet data (e.g. header data, packet size data, etc.), transmission frequencies, etc. Sampling the network traffic patterns **141** may also be performed by another approach.

Additionally, the data aggregation module **134** may also aggregate predefined configuration data corresponding to one or more of the machine instances **114** including an instance type **124**, network configuration **127**, or disk configuration **131**. The data aggregation module **134** may also aggregate other usage data **135** or configuration data.

After the data aggregation module **134** has aggregated the usage data **135** and configuration data for one or more machine instances **114**, the data aggregation module **134** then attempts to identify at least one of the applications **121** executed in a machine instance **114**. This identification may be the specific application, an application type (e.g. database application, encoding application, website application, etc.), or an application suite that performs particular functionality.

In some embodiments, this may comprise calculating a score or probability with respect to one or more potential applications **121**, and identifying the one of the potential applications **121** as being executed in the machine instance **114** responsive to the score or probability exceeding a threshold, or being the highest amongst a plurality of scores or probabilities.

Calculating a score or weight with respect to an application **121** based at least in part on the aggregated data may be performed by querying an identification knowledge base **144** relating an application **121** to one or more criteria indicative of its execution in a machine instance **114**. For example, the identification knowledge base **144** may define one or more network ports opened by default upon execution of an associated application **121**. The default network port being open in a machine instance **114** may increase a score or probability that the application **121** is being executed in the machine instance. As another example, a machine instance **114** with a large amount of disk space allocated, or implementing data redundancy such as a RAID configuration may be indicative of a database server being executed in the machine instance **114**. The identification knowledge base **144** may embody known best practices, known default application **121** configurations or operations, groupings of related applications **121** more likely to be executed together or in communication with each other, or potentially other data indicative of an application **121** being executed in a machine instance **114**.

Aggregated data associated with multiple machine instances **114** or machine instances **114** distinct from a machine instance **114** for which applications **121** are being identified may also be a factor in identifying an application **121**. For example, a network configuration **127** of a first machine instance **114** which accepts traffic from a second machine instance **114** coupled with no other machine instances **114** being configured to accept inbound network traffic from the first machine instance **114** may be indicative of a database server or a data storage service application **121** being executed in the first machine instance **114**. Aggregated data associated with multiple machine instances **114** may also be used to identify an application **121** by another approach.

Additionally, applications **121** known to be executed in a machine instance **114** or previously identified by the inventory application **117** may also factor in identifying an application **121**. For example, an application **121** may be more likely to be identified as a data analytics application **121** if the machine instance **114** is known to be executing a database server application **121** or is in network communication with a machine instance **114** executing a database server application **121**. Known or previously identified applications **121** may also be used to identify an application **121** by another approach.

In some embodiments, a score or probability with respect to multiple potential applications **121** may increase responsive to aggregated data indicating that the multiple applications **121** are being executed in the machine instance **114**. For example, a score or probability that a web server application **121** is being executed may increase as the score of a distinct web server front end application **121** increases, indicating that both the web server and its associated front end are being executed in the machine instance **114**. Indicia of multiple applications **121** being executed in a machine instance **114** may also be used to identify an application **121** by another approach.

After one or more applications **121** has been identified as being executed in a machine instance **114**, the inventory application **117** may then store the identity of the application **121** in an application profile **147**. Application profiles **147** embody which applications **121** were identified as being executed in a particular machine instance **114** at a particular time. The application profiles **147** may also comprise metadata **151** associated with the machine instance **114** including a machine instance **114** identifier, customer account identifier, instance type **124** identifier, or other data.

After one or more application profiles **147** have been stored, the reporting module **154** may generate a report **157** based at least in part on the application profiles **147**. The report **157** may be generated responsive to a query from a client **104**, responsive to the passage of a time interval, or responsive to some other criterion. The report **157** may embody, for example, analytics indicating adoption, usage, or installation rates for applications **121**, and potentially other data. The data embodied in the report **157** may be broken down with respect to data center region, application **121** vendor, machine instance **114** customer, or some other category. Other data may also be embodied in the reports **157** as can be appreciated.

After generating the report **157**, the reporting module **154** may communicate the report **157** to a client **104** via the network **107**, store the report **157** in a data store **111**, or perform some other action with respect to the generated report **157**. The report **157** may be communicated by encoding the report into a network page communicated to the client **104**, attached or otherwise encoded in an email message or short message system (SMS) message, or communicated by some other approach.

The data stored in the data store **111** includes, for example, an identification knowledge base **144**, application profiles **147**, routing configurations **137**, network traffic patterns **141**, and potentially other data.

The client **104** is representative of a plurality of client devices that may be coupled to the network **107**. The client **104** may comprise, for example, a processor-based system such as a computer system. Such a computer system may be embodied in the form of a desktop computer, a laptop computer, personal digital assistants, cellular telephones, smartphones, set-top boxes, music players, web pads, tablet computer systems, game consoles, electronic book readers, or other devices with like capability.

The client **104** may be configured to execute various applications such as a client application **161** and/or other applications. The client application **161** may be executed in a client **104**, for example, to access network content served up by the computing environment **101** and/or other servers. To this end, the client application **161** may comprise, for example, a browser, a dedicated application, etc. The client **104** may be configured to execute applications beyond the client application **161** such as, for example, email applications, social networking applications, word processors, spreadsheets, and/or other applications. Although client **104** is depicted as being outside of computing environment **101**, it could be located inside computing environment **101**.

Next, a general description of the operation of the various components of the networked environment **100** is provided. To begin, the data aggregation module **134** of the inventory application **117** aggregates data embodying the interoperability between machine instances **114** such as usage data **135**, configuration data, and potentially other data. Aggregating usage data **135** may comprise, for example, sampling CPU usage, GPU usage, memory usage, disk accesses, or other data related to a machine instance **114** accessing computing resources of the computing environment **101**. The data aggregation module **134** may also record network traffic patterns **141** by sampling network traffic packets communicated to or from a machine instance **114**.

Sampling configuration data may comprise obtaining predefined limits of allocated CPU usage, disk space allocation, memory allocation, GPU usage, or other limitations on access to computing resources of a computing environment **101** by a machine instance **114**. Such limits may be embodied in an instance type **124** associated with a machine instance **114**. For example, a customer who purchased access to a machine instance **114** may have selected one of a predefined list of instance types **124**, which allocate a predefined amount of CPU, disk, and memory, as part of the purchase transaction.

Sampling configuration data may also comprise obtaining a routing configuration **137** associated with one or more of the machine instances **114**. The routing configuration **137** may define, for example, network traffic routing paths between machine instances **114** or between a machine instance **114** and an external network **107** location. The routing configuration **137** may define connections to a load balancer, switch, router, or other networking component of the network **107** or the computing environment **101**.

Obtaining configuration data may also comprise obtaining network configurations **127** defined with respect to one or more of the machine instances **114**, or the interoperability of multiple machine instances **114**. Obtaining network configurations **127** may comprise scanning for open network ports of a machine instance **114**, loading a predefined network configuration **127** data associated with the machine instance **114**, or another approach. Loading the predefined network configuration **127** may comprise loading a customer-defined security policy embodying accessible network ports, allowable network protocols, and allowable network traffic sources, or other data defined with respect to one or more of the machine instances **114**.

Obtaining configuration data may also comprise obtaining disk configurations **131** associated with a machine instance **114**, including RAID configurations, disk partitioning schemes, data redundancy schemes or other parameters.

After obtaining the usage data **135** and configuration data, the data aggregation module **134** then attempts to identify at least one application **121** executed in a machine instance **114**. In some embodiments, this may comprise calculating a score or probability with respect to a plurality of potential applications **121** and identifying the highest scoring or most probable of the potential applications **121** as being executed in the machine instance **114**. In other embodiments, this may comprise calculating a score or probability with respect to a plurality of potential applications **121** and identifying those of the potential applications **121** whose probability or score exceeds a threshold as being executed in the machine instance **114**.

In embodiments in which a score or probability is calculated with respect potential applications **121**, the score or probability may be calculated by determining which criteria embodied in an identification knowledge base **144** entry associated with a respective potential application **121** are satisfied based at least in part on the aggregated usage data **135**, configuration data, or other data. The score or probability may also be calculated or weighted based at least in part on applications **121** previously identified or known to be executed in the current machine instance **114** or in a machine instance **114** with which the current machine instance **114** communicates.

In other embodiments, identifying an application **121** executed in a machine instance **114** may comprise applying a supervised machine learning algorithm to the aggregated usage data **135** and configuration data and a knowledge base embodied in an identification knowledge base **144**. Applications **121** executed in a machine instance **114** may also be identified by other approaches.

After at least one application **121** has been identified as being executed in a machine instance **114**, the identification is stored in an application profile **147** defined with respect to the machine instance **114**, a time period associated with data aggregation, or other data points. The application profile **147** may also comprise metadata **151** obtained from an instance metadata web service or application program interface, loaded from a data store **111**, or obtained by another approach.

The reporting module **154** may then generate a report **157** embodying analytics related to stored application profiles **147**. The report **157** may be generated responsive to a request from a client **104**, generated at a predefined interval, or generated responsive to some other criterion. The generated report **157** may be communicated via the network **107** to a client **104** as a short message system (SMS) message, an email attachment, a network page encoded for rendering by a browser client application **161**, or another approach. The generated report **157** may also be stored in a data store **111**. Other actions may also be taken with respect to the generated report **157**.

FIGS. **2**A-**2**D represent various levels of detail for a data center architecture **200** according to various embodiments. The various components of the data center architecture **200** described in FIGS. **2**A-**2**D and their various subcomponents as will be described are representative an example implementation of a computing environment **101** (FIG. **1**) to facilitate the execution of machine instances **114** (FIG. **1**).

FIG. **2**A represents a region-level view of an example data center architecture **200** according to various embodiments. Regions **201***a-n* are a plurality of logical groupings comprising a plurality of availability zones **204***a-n* and **205***a-n*. Regions **201***a-n* may be grouped based at least in part on geography, national boundaries, a logical or graphical topology, or some other approach. For example, regions **201***a-n* may be grouped by geographical areas of the United States, such as the southeast, the midwest, the northeast, or other geographical areas. Other approaches may also be used to define regions **201***a-n*.

Each region **201***a-n* comprises one or more availability zones **204***a-n* or **205***a-n*. Each of the availability zones **204***a-n* or **205***a-n* are logical groupings comprising one or more data centers **207***a-n*, **208***a-n*, **209***a-n*, and **210***a-n*. Availability zones **204***a-n* or **205***a-n* are defined to be insulated from failures in other availability zones **204***a-n* or **205***a-n*, and to optimize latency costs associated with connectivity to other availability zones **204***a-n* or **205***a-n* in the same region **201***a-n*. For example, distinct availability zones **204***a-n* or **205***a-n* may comprise distinct networks, power circuits, generators, or other components. Additionally, in some embodiments, a single data center **207***a-n*, **208***a-n*, **209***a-n*, or **210***a-n* may comprise multiple availability zones **204***a-n* or **205***a-n*. The regions **201***a-n* are in data communication with each other through a network **107** (FIG. **1**).

In some embodiments, network traffic patterns **141** (FIG. **1**) may embody patterns of network communications with respect to source or destination regions **201***a-n*, availability zones **204***a-n* or **205***a-n*, data centers **207***a-n*, **208***a-n*, **209***a-n*, or **210***a-n*, or other components of the data center architecture **200**.

FIG. **2**B depicts a data center-level view of an example data center architecture **200**. The data center-level view may be representative of an architecture implemented in data center **207***a-n*, **208***a-n*, **209***a-n*, or **210***a-n*. Data center **207***a* comprises at least one rack collection **211***a-n*, and each rack collection **211***a-n* comprises a corresponding at least one rack **214***a-n* or **215***a-n*. The data center **207***a* may also comprise at least one service rack collection **216** comprising racks **217***a-n* to facilitate the implementation of machine instances **114** (FIG. **1**).

Each rack collection **211***a-n* or **216** also comprises at least one power system **217***a-n* or **219** to which the corresponding grouping or racks **214***a-n*, **215***a-n*, or **217***a-n* are connected. Power systems **217***a-n* or **219** may comprise cabling, switches, batteries, uninterrupted power supplies, generators, or other components implemented to facilitate the powering of racks **214***a-n*, **215***a-n*, or **217***a-n*.

Each rack collection **211***a-n* or **216** is coupled to a local network **221***a-n* or **222**. The local networks **221***a-n* or **222** are implemented to facilitate data communications between the components of the corresponding rack collection **211***a-n*. The local networks **221***a-n* or **222** may also facilitate data communications between the corresponding rack collection **211***a-n* or **216** and the network **107**. In some embodiments, network traffic patterns **141** (FIG. **1**) may embody patterns of network communications with respect to source or destination rack collection **211***a-n* or **216**, racks **214***a-n*, **215***a-n*, or **217***a-n*, or other components of the data center architecture **207***a*.

FIG. **2**C depicts a rack collection-level implementation of a data center architecture **200** according to various embodiments. The rack collection-level implementation may be representative of a rack collection **211***a-n* or **216**. For example, the rack collection **211***a* comprises a plurality of racks **214***a-n*, subdivided into subsets of racks **214***a-g* and racks **214***h-n*. Each rack **214***a-n* comprises a plurality of servers **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n* and potentially other functionality. Each server **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n* may comprise shared or distinct hardware configurations. Each of the racks **214***a-n* also comprises at least one switch **227***a-n* to which the corresponding servers **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n*. The rack collection **221***a* also comprises a hierarchy of aggregation routers **231***a-n*. Although FIG. **2**C depicts a two-level hierarchy of aggregation routers **231***a-n*, it is understood that one or more levels of aggregation routers **231***a-n* may be implemented. The highest level of the aggregation routers **231***a-n* are in communication with an external network **107** (FIG. **1**).

The aggregation routers **231***a-n* facilitate the routing of network communications to the servers **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n*. To this end, each of the switches **227***a-n* are in data communication with the aggregation routers **231***a-n*.

In some embodiments, network traffic patterns **141** (FIG. **1**) may embody patterns of network communications with respect to servers **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n*, racks **214***a-n*, or other components of the data center architecture **211***a*. Additionally, in some embodiments, routing configurations **137** (FIG. **1**) may embody configurations associated with switches **227***a-n*, servers **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n*, aggregation routers **231***a-n* or other components of the data center architecture **211***a*.

FIG. **2**D depicts a server **221***a* as implemented in a data center architecture **200**. Although FIG. **2**D is drawn to server **221***a*, it is understood that FIG. **2**D may be representative of any server **221***a-n*, **222***a-n*, **223***a-n*, or **224***a-n*.

Executed on server **221***a* are one or more machine instances **114**. The machine instance **234** comprises a virtualized instance of an operating system to facilitate the execution of services, applications, or other functionality. Each machine instance **114** communicates with a virtualization layer **237**. The virtualization layer **227** controls access to the hardware layer **231** by each of the executed machine instances **234**. The virtualization layer **237** may further comprised a privileged domain **244**. The privileged domain **244** may comprise a machine instance **234** with distinct or higher-level user privileges with respect to the other executed machine instances **234** in order to facilitate interactions between machine instances **234**, the hardware layer **241**, or other components. The privileged domain **244** may also comprise access restrictions, limiting operation of the privileged domain **244** to an authorized subset of users such as a system administrator. The privileged domain **224** may facilitate the creation and management of machine instances **234**.

The hardware layer **241** comprises various hardware components implemented to facilitate the operation of machine instances **234** and their associated executed functionality. The hardware layer **241** may comprise network interface cards, network routing components, processors, memories, storage devices, or other components. In some embodiments, usage data **135** may comprise a rate of usage or access of the virtualization layer **237**, hardware layer **241**, or other components of the server **221***a*.

Referring next to FIG. **3**A, shown is an example report **157** (FIG. **1**) encoded by the reporting module **154** (FIG. **1**) for communication to a client **104** (FIG. **1**). In some embodiments, the user interface depicted in FIG. **3**A comprises a network page encoded for rendering by a browser client application **161** (FIG. **1**). In the alternative, the user interface may comprise data encoded for rendering by a dedicated client application **161**.

Item **301** depicts a report **157** detailing the use of applications **121** for a particular vendor as implemented in machine instances **114** (FIG. **1**), broken down by data center region and individual application **121**. Item **304** is a uniform resource locator (URL) directed to a network page embodying the report **157**. Item **307** is a text identifier corresponding to the name of the vendor with respect to which the report **157** was generated. Item **311** is a text identifier indicating the data embodied in the report **157**.

Item **314** is a table column whose cells define a data center region to which the other cells in the row correspond. Item **317** is a table column whose cells define three different applications **121** sold by the vendor. Item **321** is a usage rate of the corresponding application **121** in the corresponding data center region. Item **324** is a usage rate of competing applications **121** in the corresponding data center region. Other statistics, such as the number of running instances of the application, among others, could be made available in the same manner.

Turning now to FIG. **3**B, shown is an example report **157** (FIG. **1**) encoded by the reporting module **154** (FIG. **1**) for communication to a client **104** (FIG. **1**). In some embodiments, the user interface depicted in FIG. **3**B comprises a network page encoded for rendering by a browser client application **161** (FIG. **1**). In the alternative, the user interface may comprise data encoded for rendering by a dedicated client application **161**.

Item **331** depicts a report **157** detailing the use of applications **121** as implemented in machine instances **114** (FIG. **1**) for the US-East data center region, broken down by data center region and application **121** vendor. Item **334** is a uniform resource locator (URL) directed to a network page embodying the report **157**. Item **337** is a text identifier corresponding to the name of the data center region with respect to which the report **157** was generated. Item **341** is a text identifier indicating the data embodied in the report **157**.

Item **344** is a table column whose cells define a vendor to which the application **121** usage corresponds. Item **347** is a table column whose cells embody application **121** usage in the US-East data center region for the corresponding vendor. Item **351** is a pie chart generated to embody the data described in items **344** and **347**.

Moving on to FIG. **4**, shown is a flowchart that provides one example of the operation of a portion of the inventory application **117** (FIG. **1**) according to various embodiments. It is understood that the flowchart of FIG. **4** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the inventory application **117** as described herein. As an alternative, the flowchart of FIG. **4** may be viewed as depicting an example of steps of a method implemented in the computing environment **101** (FIG. **1**) according to one or more embodiments.

Beginning with box **401**, the data aggregation module **134** (FIG. **1**) of the inventory application **117** generates network traffic patterns **141** (FIG. **1**) and usage data **135** (FIG. **1**) for machine instances **114** (FIG. **1**). Generating the usage data **135** may comprise, for example, sampling CPU usage, GPU usage, memory usage, disk accesses, or other data related to a machine instance **114** accessing computing resources of the computing environment **101**. Generating the network traffic patterns **141** may comprise sniffing or monitoring network packets in communication with the machine instances **114** to determine networking protocols, source network addresses, destination network addresses, or other information. The usage data **135** and the network traffic patterns **141** may also be generated by other approaches.

Next, in box **404**, the data aggregation module **134** obtains a network configuration **127** (FIG. **1**), instance type **124** (FIG. **1**), and routing configuration **137** (FIG. **1**) associated with the machine instances **114**. The network configuration **127**, instance type **124**, and routing configuration **137** may be obtained from a data store **111** (FIG. **1**). The network configuration **127** may also be generated by performing a port scan, network probing, or other operation with respect to a machine instance **114**. The routing configuration **137** may also be obtained by querying an application program interface or other functionality of a networking component such as a router, switch, or a load balancer. The network configuration **127**, instance type **124**, and routing configuration **137** may also be obtained by another approach.

In box **407**, the data aggregation module **134** then obtains previously generated identifications of applications **121** (FIG. **1**) being executed in the machine instances **114**. This may comprise loading an application profile **147** (FIG. **1**) associated with the machine instances **114** from a data store **111**. This may also comprise accessing an identification of an application **121** identified by a concurrently executed process of the data aggregation module **134** or an identification stored in a locally accessible memory. Obtaining previously generated identifications of applications **121** may also be performed by another approach.

Next, in box **411**, the data aggregation module **134** then identifies at least one application **121** executed in one of the machine instances **114**. This may comprise, for example, calculating a score or percentage with respect to a plurality of potential applications **121** and identifying the one of the potential applications **121** having the highest score or percentage as being executed in the machine instance **114**. This may also comprise identifying those of the potential applications **121** whose score or percentage exceeds a threshold as being executed in the machine instance **114**. The scores or percentages may be calculated based at least in part on criteria embodied in an identification knowledge base **144** (FIG. **1**) being satisfied as determined by data embodied in the usage data **135**, network traffic patterns **141**, network configuration **127**, instance type **124**, routing configuration **137**, previously identified applications **121**, or potentially other data.

After identifying at least one application **121** being executed in a machine instance **114**, in box **414**, the identification of the application **121** and metadata **151** (FIG. **1**) are stored as an application profile **147** entry associated with the machine instance **114** in which the application **121** was identified. The metadata **151** may be obtained by querying a web service, obtained from a data store **111**, or obtained by another approach.

With reference to FIG. **5**, shown is a schematic block diagram of the computing environment **101** according to an embodiment of the present disclosure. The computing environment **101** includes one or more computing devices **501**. Each computing device **501** includes at least one processor circuit, for example, having a processor **502** and a memory **504**, both of which are coupled to a local interface **507**. To this end, each computing device **501** may comprise, for example, at least one server computer or like device. The local interface **507** may comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

Stored in the memory **504** are both data and several components that are executable by the processor **502**. In particular, stored in the memory **504** and executable by the processor **502** are machine instances **114**, an inventory application **117**, and potentially other applications. Also stored in the memory **504** may be a data store **111** storing usage data **135**, routing configurations **137**, network traffic patterns **141**, an identification knowledge base **144**, application profiles **147**, and other data. In addition, an operating system may be stored in the memory **504** and executable by the processor **502**.

It is understood that there may be other applications that are stored in the memory **504** and are executable by the processor **502** as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed such as, for example, C, C++, C#, Objective C, Java®, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Flash®, or other programming languages.

A number of software components are stored in the memory **504** and are executable by the processor **502**. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor **502**. Examples of executable programs may be, for example, a compiled program that can be translated into machine code in a format that can be loaded into a random access portion of the memory **504** and run by the processor **502**, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory **504** and executed by the processor **502**, or source code that may be interpreted by another executable program to generate instructions in a random access portion of the memory **504** to be executed by the processor **502**, etc. An executable program may be stored in any portion or component of the memory **504** including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, USB flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other memory components.

The memory **504** is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory **504** may comprise, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, and/or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may comprise, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may comprise, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

Also, the processor **502** may represent multiple processors **502** and/or multiple processor cores and the memory **504** may represent multiple memories **504** that operate in parallel processing circuits, respectively. In such a case, the local interface **507** may be an appropriate network that facilitates communication between any two of the multiple processors **502**, between any processor **502** and any of the memories **504**, or between any two of the memories **504**, etc. The local interface **507** may comprise additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor **502** may be of electrical or of some other available construction.

Although the inventory application **117**, and other various systems described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, etc. Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

The flowchart of FIG. **4** shows the functionality and operation of an implementation of portions of the inventory application **117**. If embodied in software, each block may represent a module, segment, or portion of code that comprises program instructions to implement the specified logical function(s). The program instructions may be embodied in the form of source code that comprises human-readable statements written in a programming language or machine code that comprises numerical instructions recognizable by a suitable execution system such as a processor **502** in a computer system or other system. The machine code may be converted from the source code, etc. If embodied in hardware, each block may represent a circuit or a number of interconnected circuits to implement the specified logical function(s).

Although the flowchart of FIG. **4** shows a specific order of execution, it is understood that the order of execution may differ from that which is depicted. For example, the order of execution of two or more blocks may be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIG. **4** may be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the blocks shown in FIG. **4** may be skipped or omitted. In addition, any number of counters, state variables, warning semaphores, or messages might be added to the logical flow described herein, for purposes of enhanced utility, accounting, performance measurement, or providing troubleshooting aids, etc. It is understood that all such variations are within the scope of the present disclosure.

Also, any logic or application described herein, including an inventory application **117**, that comprises software or code can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor **502** in a computer system or other system. In this sense, the logic may comprise, for example, statements including instructions and declarations that can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a "computer-readable medium" can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

The computer-readable medium can comprise any one of many physical media such as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM) and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

Therefore, the following is claimed:

1. A non-transitory computer-readable medium embodying a program executable in at least one computing device, the program, when executed, causing the at least one computing device to at least:

obtain a disk configuration of one of a plurality of machine instances executing a plurality of applications;

obtain a network traffic permissions configuration of the one of machine instances, the network traffic permissions configuration defining at least one of an open port, a set of network addresses, or a networking protocol for which the one of the machine instances is configured to accept network traffic;

obtain a network traffic routing configuration associated with one of the machine instances, the network traffic routing configuration defining a network traffic flow between the one of the machine instances and a distinct one of the machine instances;

identify, without an internal inspection of the machine instance, a first one of the applications based at least in part on the disk configuration, the network traffic routing configuration, the network traffic permissions configuration, and an identification of a second one of the applications;

store an identification of the first one of the applications as one of a plurality of identifications stored in a data store;

generate an analytics report embodying the identifications.

2. The non-transitory computer-readable medium of claim **1**, wherein the program further causes the at least one computing device to:

determine whether the one of the machine instances is connected to a load balancing service; and

wherein the at least one application is identified based at least in part on the determination.

3. The non-transitory computer-readable medium of claim **1**, wherein the program further causes the at least one computing device to determine at least one of a central processing unit (CPU) usage, a graphics processing unit (GPU) usage, a disk usage, or a memory usage associated with the one of the machine instances; and

wherein the at least one application is identified based at least in part on the central processing unit (CPU) usage, the graphics processing unit (GPU) usage, the disk usage, or the memory usage.

4. A system, comprising:

at least one computing device configured to at least:

obtain data embodying an interoperability between at least a subset of a plurality of machine instances, the data comprising a disk configuration, a network traffic routing configuration, a network traffic permissions configuration, and an identification of a first application;

generate an identification for at least one second application executed in one of the machine instances based at least in part on the data without an internal inspection of the machine instance.

5. The system of claim **4**, wherein generating the identification further comprises:

calculating a probability that the identification corresponds to the at least one second application based at least in part on the data; and

associating the identification with the at least one second application responsive to the probability exceeding a threshold.

6. The system of claim **4**, wherein the data further comprises network traffic permissions define at least one of a set of network addresses or a networking protocol for which the one of the machine instances accepts network traffic.

7. The system of claim **4**, wherein the network traffic routing configuration defines a network traffic flow between the one of the machine instances and a distinct one of the machine instances and the identification is generated based at least in part on the network traffic routing configuration.

8. The system of claim **4**, wherein the network traffic permissions indicate an open network port, and identification is generated based at least in part on the open network port being a default open network port for the at least one second application.

9. The system of claim **4**, wherein the disk configuration comprises a redundant array of independent disks (RAID) configuration for the one of the machine instances; and

wherein the identification is generated based at least in part on the RAID configuration.

10. The system of claim **4**, wherein the data comprises a load balancing configuration.

11. The system of claim **4**, wherein the at least one computing device is further configured to at least:

determine at least one of a central processing unit (CPU) usage, a graphics processing unit (GPU) usage, a disk usage, or a memory usage associated with the one of the machine instances; and

wherein the identification is generated based at least in part on the CPU usage, the GPU usage, the disk usage, or the memory usage.

12. The system of claim **4**, wherein the identification is generated based at least in part on a disk size of the machine instance.

13. The system of claim **4**, wherein the one of the machine instances is associated with an instance type defining at least one of a memory usage threshold, input/output (I/O) threshold, CPU usage threshold, or GPU usage threshold, and the identification is generated based at least in part on the instance type.

14. The system of claim **4**, wherein the network traffic permissions are defined with respect to the subset of the machine instances.

15. The system of claim **4**, wherein the at least one computing device is further configured to at least:

store the identification as one of a plurality of identifications; and

generate an analytics report based at least in part on the identifications.

16. A method, comprising:

obtaining, in one or more computing devices, data embodying operational interoperability between a subset of a plurality of machine instances executing at least one application, the data comprising a disk configuration, a network traffic routing configuration, a network traffic permissions configuration, and an identification of another application; and

identifying, in the computing device, the at least one application based at least in part on the data without an internal inspection of the plurality of machine instances.

17. The method of claim **16**, wherein identifying the at least one application comprises:

calculating, in the computing device, a plurality of scores each corresponding to one of a plurality of potential application identities; and

identifying, in the computing device, the at least one application as a one of the potential application identities having the highest score.

18. The method of claim **16**, wherein the disk configuration comprises at least one of a RAID configuration, a disk size, or a disk partitioning.

19. The method of claim **16**, wherein the one of the machine instances is associated with an instance type defining at least one of a memory usage threshold, input/output

(I/O) threshold, CPU usage threshold, or GPU usage threshold, and the identification is generated based at least in part on the instance type.

20. The method of claim **16**, wherein the network traffic permissions configuration defines at least one of a set of network addresses or a networking protocol for which the one of the machine instances accepts network traffic.

21. The method of claim **16**, further comprising:

identifying, in the computing device, a network traffic pattern embodying network communications between the subset of the machine instances; and

wherein identifying the at least one application is performed based at least in part on the network traffic pattern.

22. The method of claim **16**, further comprising:

storing, in the computing device, an identifier of the at least one application in a data store; and

generating, in the computing device, an analytics report embodying the identifier and a plurality of previously stored identifiers.

23. The method of claim **16**, wherein the network traffic routing configuration defines a network traffic flow between the subset of the machine instances.

24. The method of claim **16**, wherein the traffic permissions are defined with respect to the subset of the machine instances.

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